IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Scott J. Clifford et al.	)
	) Group Art Unit: 1734
Serial No.: 10/691,763	)
	) Examiner: G. Koch
Filed: October 23, 2003	)
	) Attorney Docket: 132815-7
For: Modular Painting Apparatus	) (formerly 16129)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF SCOTT J. CLIFFORD and PAUL COPIOLI UNDER 37 CFR 1.132

Honorable Sir:

SCOTT J. CLIFFORD and PAUL COPIOLI declare as follows:

1. We are joint inventors of the subject matter of the above-identified patent application.

2. I, Scott Clifford received a Bachelor of Science degree in Applied Science in 1983 from Miami University in Oxford, Ohio.

3. I, Paul Copioli received a Master of Science degree in Aerospace Engineering from the University of Michigan in Ann Arbor, Michigan.

4. From 1989 to date, I, Scott Clifford have been employed by Fanuc Robotics America, Inc., Rochester Hills, Michigan, assignee of the above application. My present position is Principal Engineer, Paint Systems Automation Group.

5. From 1997 to date, I, Paul Copioli have been employed by Fanuc Robotics America, Inc., Rochester Hills, Michigan, assignee of the above application. My present position is Senior Staff Engineer, Product Development.

6. Through our work at Fanuc Robotics America, we are familiar with the construction and operation of robots for performing painting operations.

7. We have studied the examiners rejections and offer the following information to support our claims. Please see attached document.

8. I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-referenced application or any patent issuing thereon.

Date: July 19, 2007 By Scott J. Clifford

Scott J. Clifford

Date: July 19, 2007 By Paul Copioli

Paul Copioli

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ATTACHMENT TO DECLARATION OF INVENTORS SCOTT CLIFFORD AND PAUL COPIOLI

Declaration Document July 17, 2007

Why FANUC Robotics should gain patent protection for the P-500 structure/kinematics patent, Serial No.: 10/691,763 (Filed October 23, 2003):

> The development matched industry needs with a significant improvement in key performance areas. This apparatus was original and never utilized in the industry until the introduction of the P-500 painting machine.

> It may appear that the design is obvious given its simplicity; however, in practice, it is more difficult to simplify the design of a robotic painting machine, rather than to make it more complex. Painting machines of the past included 3, 4, 6 and 7 axes. Multiple 5-axis painting machines, integrated into a common structure using an optimized linear/rotary kinematics chain, is novel.

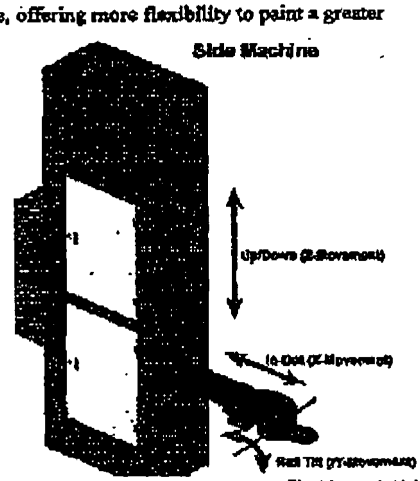
> The level of innovation is proportional to market success. Market success is a factor of the machine design. Additionally, the accomplishment was not gained through sales promotion. Finally, the product innovation is recognized by industry champions.

The innovation and proportional development expense is worthy of protection. The development challenges to meet the market needs required careful consideration of each design element of the product. The following explanation is offered to provide a better understanding of the invention and its value to the industry.

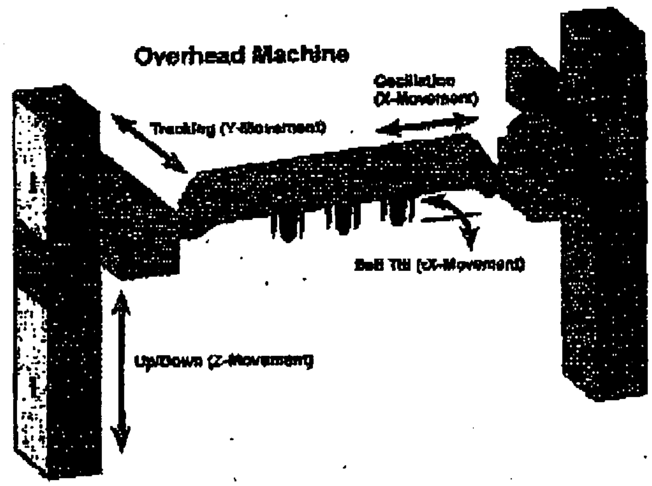
Background – Evolution of Automotive Exterior Painting

Prior to the year 2000, bell zones were often used for exterior painting. Bell zones were first introduced in the early 1980's with the advent of the rotary atomizer (bell applicator). The rotary atomizer replaced the spray gun primarily in the moving line exterior painting application. The bell applicator was large and heavy but offered improvements in transfer efficiency and atomization. The bell application used less paint and improved surface appearance quality. Multiple bells were placed in fixed positions along the sides of the spray booth to paint the vertical surfaces of automobile bodies. In a similar fashion, 2-4 bells were affixed to a horizontal beam which was mounted overhead and perpendicular to conveyor travel. The beam was raised and lowered with a hydraulic cylinder and these bells applied the paint to the horizontal surfaces of a car. As the bodies were conveyed through the paint zone and the sheet metal passed in front of the atomizer, the paint flow was turned on and off.

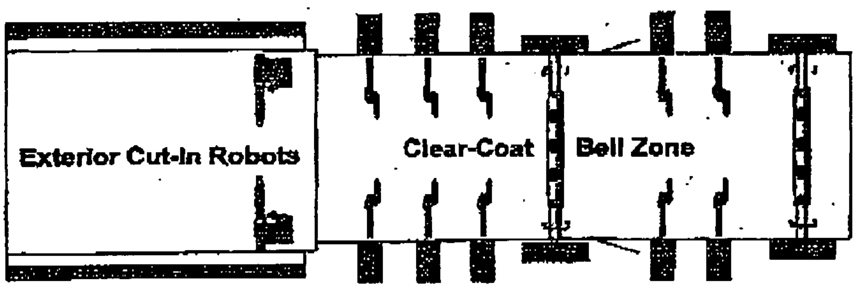
The design of the bell zone equipment continued to advance, offering more flexibility to paint a greater amount of the car body surfaces, with improved bell-to-part standoff distance. Additional degrees of freedom were added using electric servo motor control. The side and overhead machines evolved to three-axis manipulators, and the overhead machines used a fourth motor to oscillate the entire beam a short distance side to side. The mechanisms housed the motors and drive mechanisms in cabinets. The cabinets were mounted outside the spray booth, which allowed the walls of the spray booth to be drawn inward, narrowing the width of the spray booth considerably. This was called the "clean-wall" approach. A typical bell zone included six side machines, three on either side of the conveyor, and one overhead machine. The side machines were configured with one bell a piece, and the overhead machine was configured with three bells; consequently,



a nine-bell zone was commonly used to apply one layer of paint to the exterior of the car body.



Although the bell machines evolved to offer more motion flexibility, there were exterior areas of the car body — mainly the back ends of taller vehicles and the interiors of pickup trucks -- which required manual or robotic application. Below is an overview of a truck clear-coat bell zone with robotic exterior reinforcement.



There was limited use of bell applicators on robots in the 1990's. Robots outfitted with bells were used in a stop station approach for the clear-coat application (stop station, or modular, as opposed to a moving line paint shop). This application was popularized by General Motors, where the exterior and interior painting applications were conducted by rail-robots in a common spray zone. The stop station method for painting entire car bodies in a single zone lessened in popularity and the moving line systems have become the norm.

Although robots were used for automobile painting since the early 1980's, they were not widely used in moving line systems for painting the exterior surfaces of car bodies. Robots were outfitted with bells beginning in the early 1990's, but primarily used for reinforcing coverage of exterior areas that bell machines could not adequately paint, replacing manual sprayers. Areas painted included exterior surfaces such as the inside of truck boxes and the large, rear surfaces of mini-vans or SUV's. Robots were also used to paint interior cut-in areas of the vehicle bodies, including the inside of doors, under hoods and trunk interior areas. The additional flexibility of the multi-axis painting robot was a requisite to paint these areas.

In the late 1990's, Toyota began to exclusively use robots on moving line exterior applications. Toyota applied pedestal (6 axes) robots with bells to paint cars. In the early 2000's, the bell began to replace the spray gun as the method of choice for interior cut-in applications and for second-coat, metallic, exterior application. The standard painting robot began to find its way into the market; however, the design of the standard painting robot may not have been ideal.

FANUC Robotics promoted the use of bells on robots for moving line exterior painting with little success from the period of 1990 to the introduction of the P-500 in the summer of 2003. FANUC Robotics' main customers – General Motors, Ford and Chrysler – were still using bell machines for the moving line exterior application. These customers had extensive experience with painting robots used for painting other areas of the body where robots were a necessity. They were apprehensive to change to the more complex robots for painting the simpler exterior surfaces, due to lower reliability and higher cost.

Toyota replaced the traditional 9-bell zone with 4 pedestal painting robots per coat. North American manufacturers investigated this approach; however, the car bodies were larger, requiring 5-6 robots per zone in order to keep the flow rates comparable to the bell zone system. Many suppliers preferred rail-robots (7 axes) over pedestal robots (6 axes) for moving line applications. Pedestal robots have limited work envelopes and programming is more complex. The use of four robots was satisfactory for Toyota; however, North American car and truck plants run at higher line speeds, with larger vehicles. SUV's and pickup trucks are a considerable part of the product line-up. Pedestal robots are not well-suited for these vehicles; 7-axis rail-robots are typically used. North American car and truck plants had differing views on the use of robotics. Although they desired more flexibility and reduced spray booth size, application rate and equipment uptime were important factors which needed to be considered. In order to penetrate this market, FANUC Robotics was challenged to provide a painting system that provided the same reliability and simplicity of the bell zone, while offering the flexibility of the robot. This had to be accomplished in a smaller spray booth, while offering the same or better finish quality.

What problem were we trying to solve? The industry had a need for a new approach for exterior painting and using the available technology did not meet all market needs. The industry needs can be summarized below:

More Flexibility

Car Designs are More Complex Having Multi-Curved Surfaces

Run Multiple Vehicle Styles in a Single Plant

Flexibility to Change between Cars or Trucks without Adding Equipment

Reduce Capital Cost for New Paint Shops

Reduce Size of Paint Shop

Reduce Automation Equipment Cost

Improve Visibility to the Spray Zone so Observation Zones Can Be Eliminated

Reduce Operating Costs

Reduce Spray Booth Air Flow - Energy Costs

Reduce Paint Usage Per Vehicle

Reduce Daily Maintenance (Cleaning)

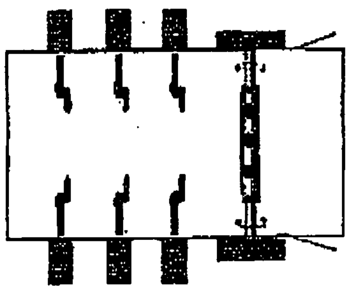
Improve Reliability and Uptime

Concept Comparisons Using Available Technology

The following comparisons show the use of available technology, the advantages and shortcomings which drove the development of the P-500 system.

Bell Zone

The 9-bell zone was the standard of the industry. The equipment was simple and reliable, but lacked the flexibility to paint the rear of SUV vehicles and the inside of pickup truck box beds. Even though the 9-bell zone had a high applicator density, it did not have ideal back-up capability. Each applicator was dedicated to paint a specific surface of the car. Work could not be easily divided in the event one applicator became inoperable.



Bell Zone	
Applicators	9
Motion Axes	22
Booth Width (ft)	15
Booth Length (ft)	30
Booth Area (ft^2)	450
Equipment Cost ($M)	1.3

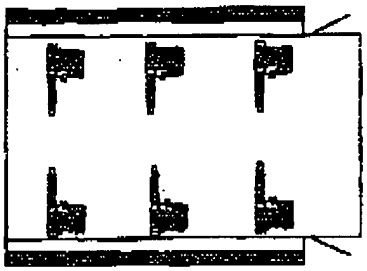
Beyond its motion flexibility limitations, the bell zone approach was not optimal in other areas. The spray booth was longer than desired. This is due to the equipment cabinets mounted outside of the spray zone. The cabinets blocked viewing and operator access into the spray booth. Access doors are typically required at the beginning or end of the spray zone. Although the spray booth is narrow, the zone was longer than desired.

A minimum of nine applicators were required to paint the exterior surfaces of a vehicle. Each time a new color is required the system performs a color change. Each color change results in 15 – 25 ml of paint waste for each bell applicator. The high number of applicators helps to keep flow rates low, but also contributes to significant amounts of wasted paint. Although the machines were very simple and reliable, the applicators were very specific to the areas to be painted. Therefore, if a machine became inoperable, the others could not readily pick up for the down applicator.

Rail-robot Zones

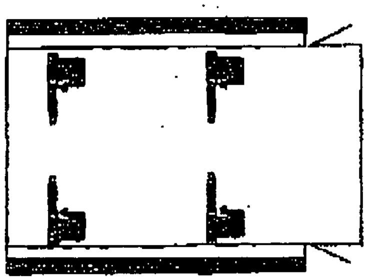
Rail-robots were often used for interior cut-in or exterior cut-in applications on moving line painting systems. The rail axis carries a 6-axis robot parallel to the direction of the conveyor. The rails are mounted at floor level, often integrated into the outside walls of the spray booth (clean-wall rail). The rail axis, also called the 7^{th} axis, is redundant and is used to expand the work envelope of the robot. It is also used to simplify the robot programming and motion play back for moving line applications. The rail axis is synchronized to the line speed so that line stopping or variability in line speed is accounted for with the rail axis. A key benefit of using a rail-robot over a pedestal robot (6-axis) is the former has the ability to move up and down the rail to ideally place the portion of the car to be painted within the robot's ideal work envelope. The applicator efficiency (the on-time divided by the available cycle time) is optimized in this fashion. Moreover, the robot's position, with respect to part position, can also be optimized.

Using 6 rail-robots provided the same, or improved, paint atomization capability as a 9-bell zone, but with enhanced flexibility to paint the difficult surfaces of the part. The 6-robot zone had the additional benefit of degrade. If one robot became inoperable, the work could be divided amongst the other five robots.



6 Rail Robots	
Applicators	6
Motion Axes	42
Booth Width (ft)	18
Booth Length (ft)	30
Booth Area (ft^2)	540
Equipment Cost ($M)	2.1

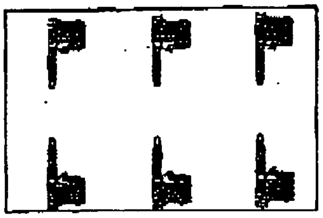
The 6- rail-robot zone provided improved flexibility, but required a much larger spray booth. Reliability and complexity was a concern as well. The floor-mounted robots blocked operator access to the spray booth; the spray booth had to be lengthened to allow room for an access door. The cost of equipment, excessive booth area and complexity made this approach undesirable.



4 Rail Robots	
Applicators	4
Motion Axes	28
Booth Width (ft)	18
Booth Length (ft)	25
Booth Area (ft^2)	450
Equipment Cost ($M)	1.4

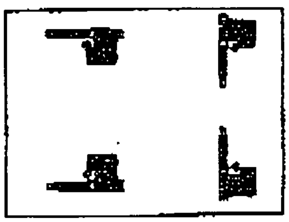
Pedestal Robot Zones

The pedestal robot has a spherical work envelope. Compared to a rail-robot, the pedestal robot has a more limited reach envelope and can only paint surfaces which are well within the spherical envelope of the robot. Because pedestal robots are not equipped with a rail axis, it is important for the robot to have the capability to paint in front of itself rather than turned to the side. This, in turn, makes the spray booth wider.



6 Pedestal Robots	
Applicators	6
Motion Axes	36
Booth Width (ft)	20
Booth Length (ft)	30
Booth Area (ft^2)	600
Equipment Cost ($M)	1.8

For small to mid-size car painting, the 4-robot solution is acceptable, yet, does not meet the cost flexibility and simplicity requirements of the U.S. manufacturers.

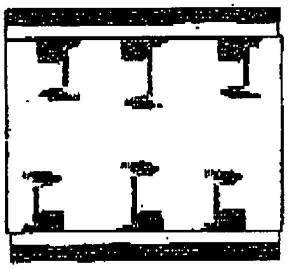


4 Pedestal Robots	
Applicators	4
Motion Axes	24
Booth Width (ft)	20
Booth Length (ft)	20
Booth Area (ft^2)	400
Equipment Cost ($M)	1.3

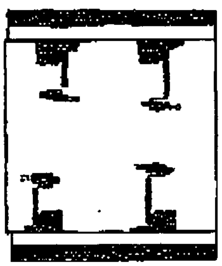
P-500 Solution

The FANUC Robotics P-500 is an innovative product for automotive exterior painting applications. Regarded by many customers as the ideal way to paint the exterior surfaces of their cars, the P-500 has eliminated the use of bell machines, traditional pedestal robots, and rail-robots.

Wide acceptance was accomplished by creating a machine that is more flexible yet less complex than 6-axis pedestal robots. It has less flexibility than a 7-axis rail-robot but sufficient flexibility so that additional robots for exterior cut-in areas are no longer needed. It can operate in the same narrow booth width as the bell zone but requires significantly less booth length.



6-Robot P-500 System	
Applicators	6
Motion Axes	30
Booth Width (ft)	15
Booth Length (ft)	25
Booth Area (ft^2)	375
Equipment Cost ($M)	1.6



4-Robot P-500 System	
Applicators	4
Motion Axes	20
Booth Width (ft)	15
Booth Length (ft)	20
Booth Area (ft^2)	300
Equipment Cost ($M)	1.2

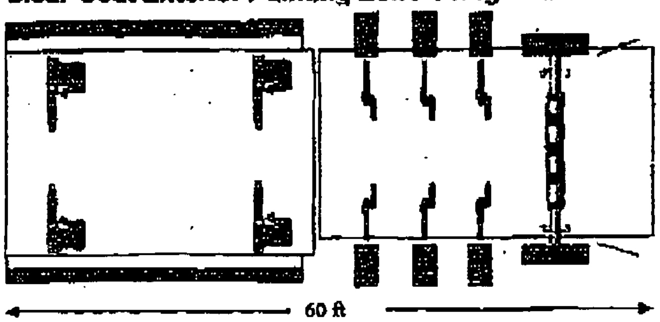
The P500 has a clear advantage in view of spray booth size and equipment cost.

	Benchmark 8-Bell Zone	6 Rail-Robots	4 Rail-Robots	8 Pedestal Robots	4 Pedestal Robots	6 P-500 Robots	4 P-500 Robots
Applicators	8	6	4	8	[illegible]	[illegible]	4
Motion Axes	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
Booth Width (ft)	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Booth Length (ft)	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Booth Area (ft^2)	460	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Equipment Cost ($M)	1.8	[illegible]	1.4	[illegible]	[illegible]	[illegible]	[illegible]

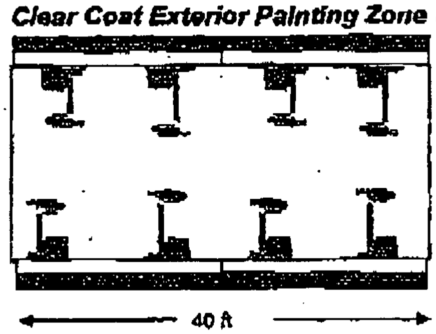
Benchmark	
Lower Performance	
Better Performance	

The following is an example of a truck painting clear coat exterior zone comparing the available technology, a combination of robots and bell zones, vs. the P-500 technology. The P-500 system offers more flexibility in a significantly smaller booth size.

Clear Coat Exterior Painting Zone Using Robots and Bell Zone



Clear Coat Exterior Painting Zone Using P-500 Bell Zone



Why develop a new robot?

In order to meet the customer needs and especially the space savings demonstrated above, a new machine had to be developed. The design of the new machine required extensive design effort and concept rationalization.

An automotive class painting robot requires special design considerations. This makes the design effort even more challenging and the robot larger than its material handling or welding counterparts. These special design features include:

a. The routing of 50 paint lines and 42 pneumatic hoses to the outer arm mounted color changer and applicator.

b. Integrating the servo motors within purge and pressurized cavities

c. Providing a very large work envelope together with high linear velocity/acceleration.

d. Protecting the robot and appurtenances from paint overspray while allowing easy access for paint equipment maintenance.

These design elements make the painting robot larger and more complex than desired. Therefore the task to get 6 painting robots to work cooperatively in a 15 x 25 foot spray zone is formidable and was never accomplished prior to the P-500.

Key development elements.

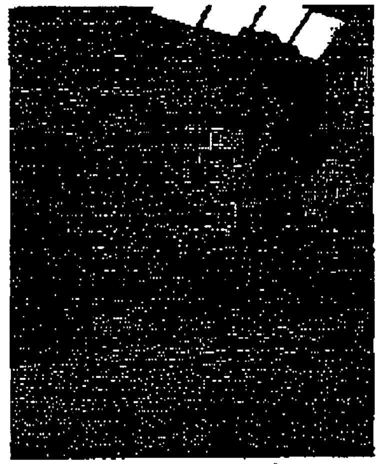
The following are the key development elements that led to the success of the P-500. Many of the design elements are confounded, meaning any change in one area effects the others to a significant level. The P-500 represents simultaneous optimization in many areas. This can also mean minimizing the compromises of how each design aspect affects the entirety of the design. We do not think of the P-500 as a painting robot but we refer to it as a painting machine where a minimum of two robots opposing each other are installed on a common structure in order to adequately paint the vehicle. Additional robots and rail length can be added to suit the size of the car and the production rate.

Optimized combination and location of rotary and linear axes to provide suitable reach to paint a small or large car, in the same cell while reducing the booth area by 25-40%.

1. Elimination of the robot waist axis and replacing with a linear axis.
2. Optimum selection of inner and outer arm placement in cooperation with the location of the J2 position (inner arm rotation).
3. Elimination of the final wrist rotation axis (J6).
4. Placement of the J2 axes below the rail (under slung) with rail height sufficiently high to allow viewing into the zone and a door to be placed beneath the rail for operator access; while at the same time being compact enough atop to fit in an existing spray booth.
5. The rail and carriage design such that the arm had sufficient rotation to reach the part while not intersecting the rail and cable carrier.
6. Connecting the rails in a rigid fashion without creating a source of dirt contamination or requiring extensive rework of existing spray booths.

If the P-500 concept was obvious, why did it take so long to get to the market? Bell zone machinery, pedestal and rail robots have been around since the early 1980s. Why did it take 20 years in an extremely competitive market place for this product to be developed? Why do many feel the product is so revolutionary yet simple at the same time?

Benefits of the P-500 Design



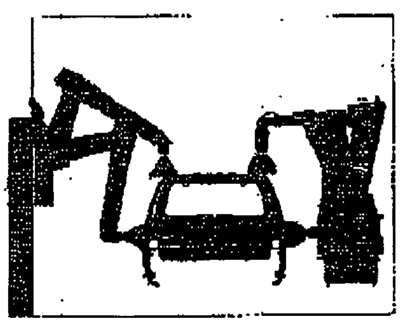
In the prior art bell machines, having too few axes required more applicators to paint the car. Having too few axes also meant that a machine designed to paint the tops of cars could not paint the sides of cars and visa-versa. The cabinets outside the spray booth blocked the viewing area and access doors had to be placed at the end of the zone.

Using a typical 6 or 7-axis painting robot required a longer or wider spray booth. Rail robots, which are highly desired in the North American market for tracking applications, provided more flexibility. The floor mounted rail robot also blocked access to the spray booth. Viewing was often obstructed by the enclosure surrounding the rail.

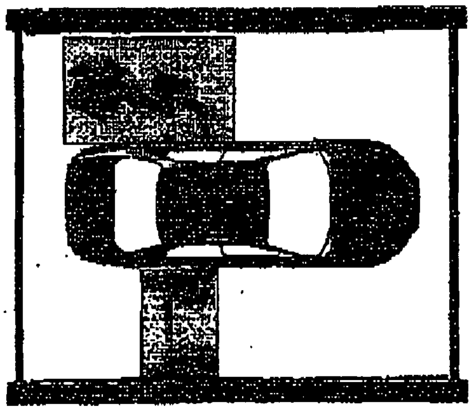
By eliminating the waist axis and careful selection of the shoulder pivot point, along with selection of the inner and outer arm link lengths, the reduced-axis elevated robot concept works well to paint the horizontal and vertical exterior surfaces of the car.

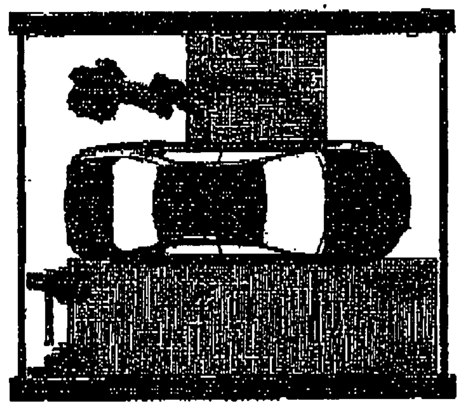
The following pictures show a 4-robot P-500 zone with the robots in various painting positions.

The following shows an elevation of a narrow spray booth with two P-500 robots on the left and two P-200 pedestal robots on the right. The pedestal robots must rotate to paint the car body in a narrow booth otherwise the arm could hit the wall or the car. Making the pedestal outer arm link lengths shorter would help in the motion range near the robot but would make the reach envelope too small for a tracking type application.



In the first picture below, the P-200 pedestal robot (top of left picture) is turned to the side whereas the P-500 has the capability to paint in front of itself. The shaded area represents the amount of space the robot occupies to paint one stroke along side of the car body. In the second slide, the shaded areas represent the flexibility of the work envelope where this single stroke can be played back within the spray zone. This demonstrates the benefits of using a first linear axis in place of the waist axis. The P-500 is the first painting robot to paint sides and tops of vehicles in this fashion without a waist axis. This demonstrates that the 5 axis robot has more capability or flexibility than a six axis robot.

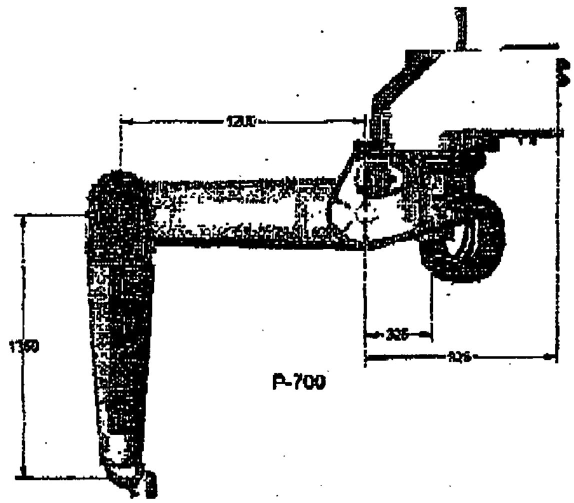


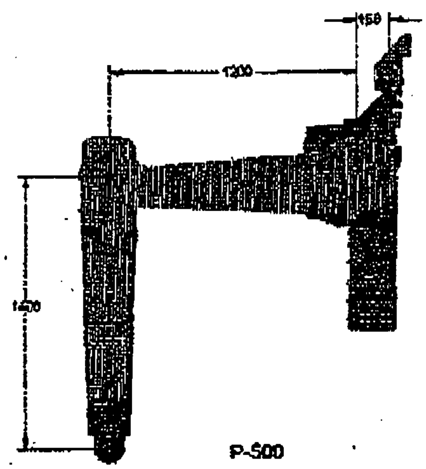


Not having a waist axis also helps to simplify the robot and make it more compact. Below is a picture of the P-500 (5 axis) on the left and the newly developed P-700 (7 axes) robot on the right. Notice the size of the robots base castings (J1 turret and rail axis). For reliability purposes, the hoses pass through the center of the J1 rotation axis on the P-700. The P-700 was developed for interior painting and the waist axis is needed. The waist axis is not required for the P-500 and exterior surface painting. The hoses make a ribbon like bend as they are carried from the mounted color changer to the cable & hose carrier atop the rail. Benefits include: smaller package, simpler teaching, less cost, and easier to maintain.

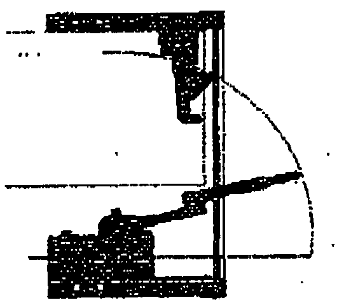
The P-700 and P-500 robots are shown below. Eliminating the robot waist axis reduces the amount of robot volume in the spray booth. It is easy to see that by eliminating the rotational J1 axis the volume of equipment in the spray booth is much less with the P-500. This allows a narrower booth and there is less obstruction effect on the spray booth downdraft.

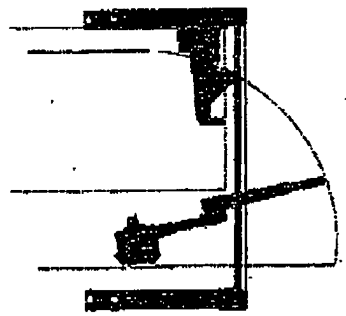
Placing the rail equipment above the roof line of the car also reduces the air velocity on the side of the car. The car body displaces a large portion of the air flow within the spray booth. Placing robot equipment at the floor level further increases the air flow at the sides of the car.





Another benefit of the simplified kinematics or the use of linear J1 in place of a rotational J1 axis is with respect to the safety zone at the end of the booth. The P-500 robot cannot exit the spary booth perimeter whereas the rail or pedestal robots can. Hard stops or additional spray booth length in conjunction with perimeter guarding circuitry must be provided to protect workers in the adjacent zones. The following pictures show a P-500 robot on the top side. The first picture shows a 7-axis rail robot on the bottom side and the second picture shows a pedestal robot on the bottom side. Either booth length or suitable blocking devices must be added to protect area outside the normal painting area.





Market Success

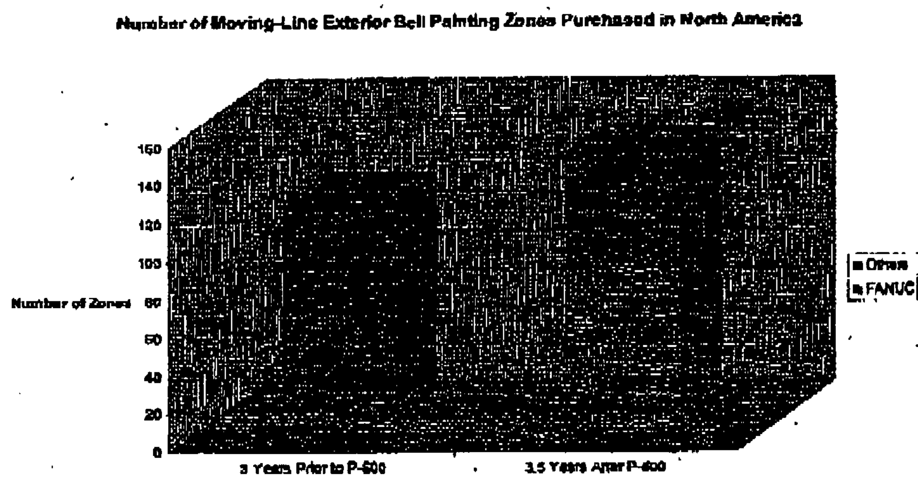
Prior to the advent of the P-500 painting system, FANUC had low market share in the bell zone exterior moving line painting systems. However, FANUC Robotics had very strong market share for interior painting systems. GM, Ford, and Chrysler purchased bell machines from Durr, ABB, and SAMES. This fact highlights the point that the state-of-the-art systems at that time for robotic painting were not well-suited for exterior moving-line painting applications.

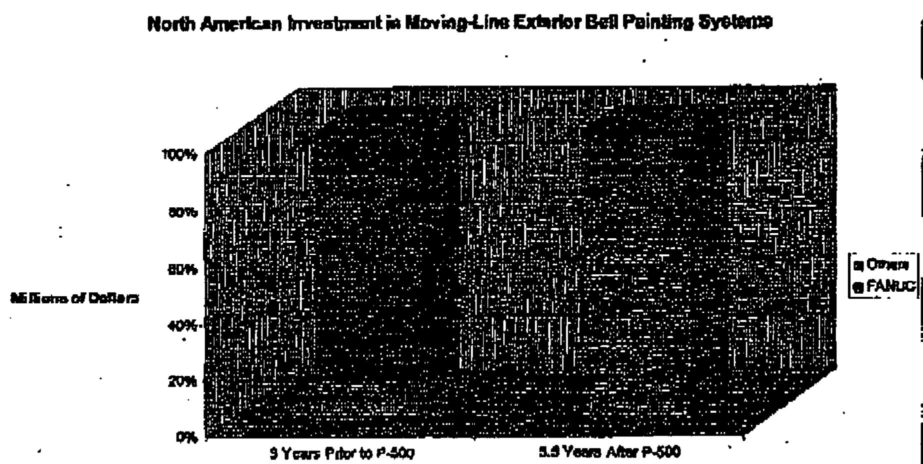
An analysis of the exterior painting market systems installed during the three years prior to the introduction of the P-500 shows that FANUC Robotics' market share in North America for moving line systems was approximately 11%. An estimated $168 million was spent on 121 exterior moving line painting zones at different automotive plants from General Motors, Ford, DaimlerChrysler, Honda, Hyundai and Nissan. Also, based on the available technology at this time, the majority of moving line systems for exteriors were bell machines as opposed to robots.

The P-500 was first installed in an automotive plant in July 2003 at Nissan in Smyrna, Tennessee. Full-scale production of the P-500 began with systems installing in January 2004. It is notable that prior to this, Nissan purchased bell machines as the standard for moving-line exterior painting but saw the unique benefits of the P-500 for this application. Many other customers would follow with this same conclusion.

The impact of the innovation provided by the P-500 can be seen from significant increase in market share for FANUC after the introduction of the P-500. For the three and one-half years after the introduction of the P-500, FANUC installed an estimated $100 million in P-500 moving line exterior painting systems in 86 zones in North America. The systems were installed in plants from General Motors, Ford, DiamlerChrysler, Nissan, Mazda, and Subaru. The total market for moving-line exterior zones estimated for this period was $157 million over 138 zones.

The innovations provided in the P-500 clearly made it the product of choice for automotive customers as indicated by the six times FANUC market share increase for exterior moving-line bell painting systems achieved after the introduction of the product. The FANUC market share for these years following the introduction of the P-500 was an estimated 65% compared to 11% prior to its introduction.





Conclusion

The elevated, multi-arm, P-500 robot system is an innovative design which changed the way we paint the exterior surfaces of a car body. Prior art designs did not answer the cumulative needs of our customers. The market success the P-500 product is a key indicator of this assertion.